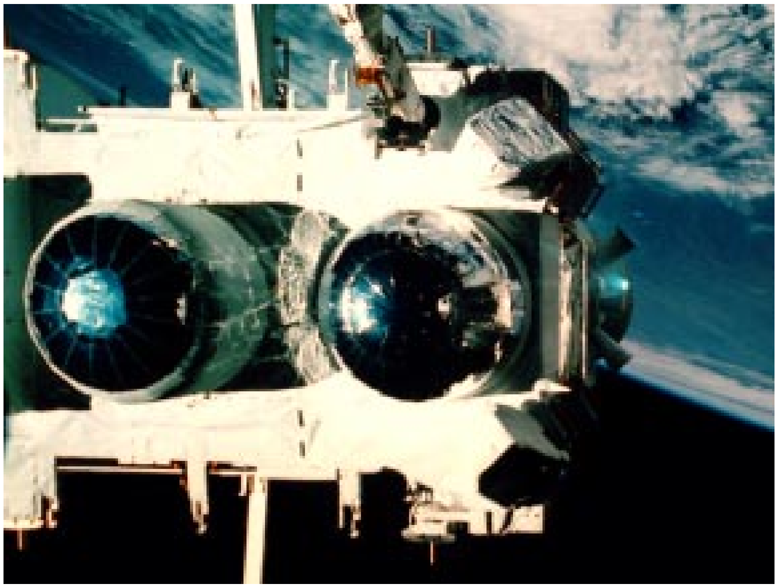
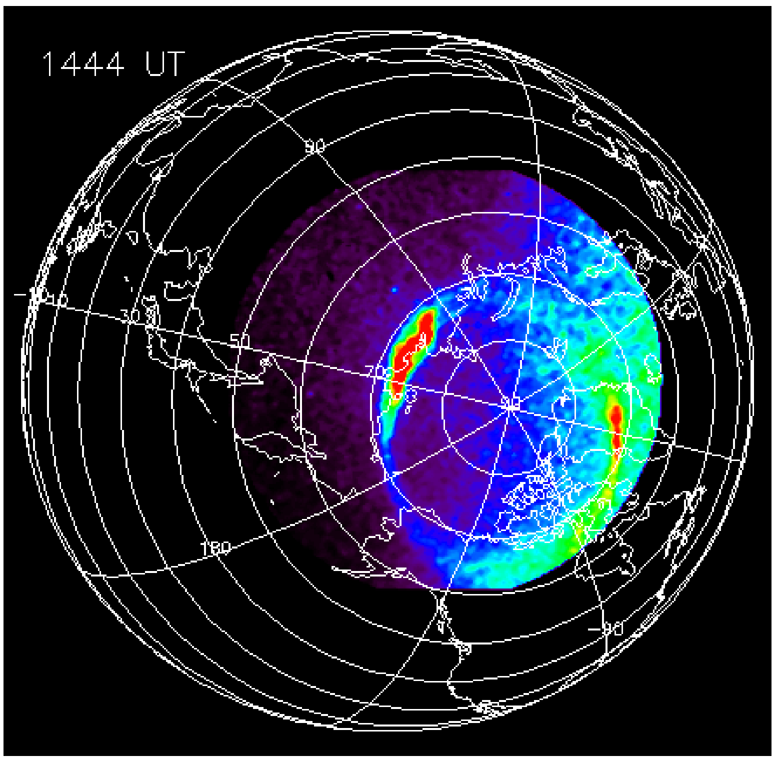


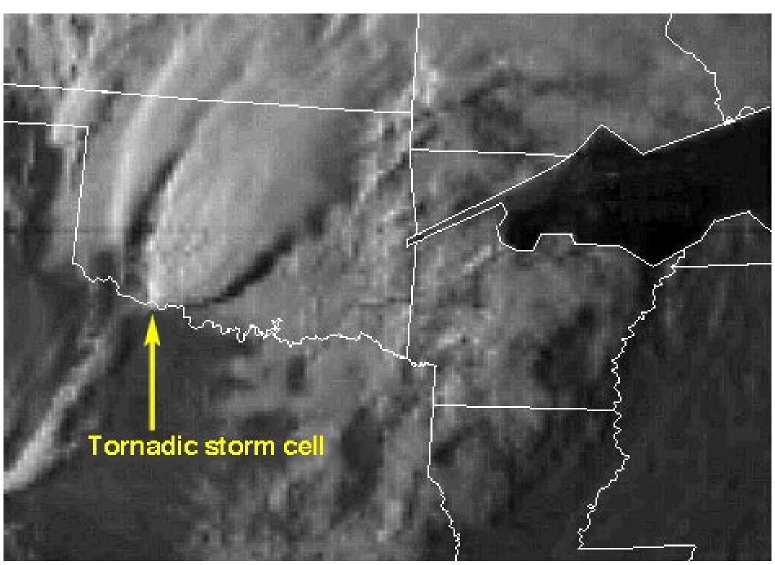
SPACE SCIENCES LABORATORY

MARSHALL SPACE FLIGHT CENTER



1996 Science Highlights

In the National Interest



http://wwwssl.msfc.nasa.gov

This view from the flight deck of Space Shuttle Columbia (STS-75, Feb. 22-March 9, 1996) encompasses the range of Space Sciences Laboratory's investigations. In the foreground is the deployment segment of the Tethered Satellite System (seen on the back cover) for plasma physics investigations. Behind that is the U.S. Microgravity Payload (USMP-3), one of several facilities used for microgravity science investigations by SSL and other labs. And beyond are the Earth, with its complex hydrological and climate systems, and the stars emitting in X-rays and gamma rays. All are studied by SSL.

The front cover depicts three of SSL's headline-makers: the detectors of the Burst and Transient Source Experiment on the Compton Gamma Ray Observatory, the full night-and-day auroral oval seen by the Ultraviolet Imager, and a visible light image of a tornadic storm cell where the Optical Transient Detector observed lightning flashes.

The back cover also depicts different aspects of SSL's work (clockwise from top right): the Advanced Automated Directional Solidification Furnace (about 3 feet tall) awaits its flight on USMP-3; the Science Systems Division builds instruments for SSL balloon flights; the shuttle starts unreeling the Tethered Satellite on STS-75; blue "worms" show lines of intense magnetic field stress in a view combining data from telescopes at SSL and aboard the *Yohkoh* satellite; and two maps show average global temperature variations for the lower troposphere (top) and lower stratosphere (bottom).

What is SSL?

1996 was another outstanding year for the Space Sciences Laboratory (SSL) as it made significant advances in our scientific knowledge and understanding of the Earth, solar system, and universe, and in the production of new materials in space.

SSL is a key part of NASA's Marshall Space Flight Center (MSFC) in Huntsville, Ala., and is the second-largest science laboratory in NASA. SSL's history predates NASA, and includes pioneering work in high-energy astrophysics, space plasma physics, solar physics, atmospheric sciences, and materials science. Today, SSL is organized into four divisions:

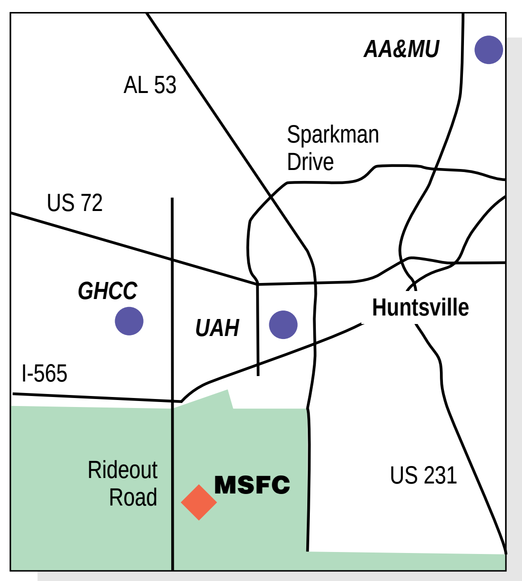
- Physics and Astronomy,
- Earth System Science,
- Microgravity Science and Applications, and
- Science Systems.

The *NASA Strategic Plan* states that a primary mission of the agency is "To advance and communicate scientific knowledge and understanding of the Earth, the solar system and the universe, and to use the environment of space for research." The division of research within SSL into Earth, space, and microgravity science reflects this tripartite mission statement. SSL research supports three (noted in italics) of NASA's four strategic enterprises: *Human Exploration and Development of Space*, *Mission to Planet Earth*, *Space Science*, and Aeronautics.

Scientists at SSL plan, coordinate, direct, and conduct original and supporting theoretical, experimental, and observational research in the first three enterprises. They also provide scientific leadership and support for Marshall Center programs. On the pages that follow, we summarize some of SSL's outstanding scientific discoveries in 1996.

Dr. Gregory S. Wilson, Director

- **Space Sciences Laboratory**
  - **Microgravity Science and Applications**
    - Crystal Growth and Solidification
    - Biophysics
  - **Earth System Science**
    - Global Hydrology & Climate
  - **Physics and Astronomy**
    - Astrophysics
    - Solar Physics
    - Space Plasma Physics
  - **Science Systems**
    - Experiment Development
    - Flight Experiments
    - Data Systems



SSL Earth Systems Science is located in Huntsville's Research Park West at the Global Hydrology and Climate Center. SSL partners with the University of Alabama in Huntsville and Alabama A&M University in operating the GHCC and in conducting other research.

Physics and Astronomy

Gamma-ray astronomy
Tethered Satellite System
Space plasma fountain
AXAF mirror development

SSL scientists drew national attention as they explored basic mysteries of the universe and what happens where the Earth meets space.

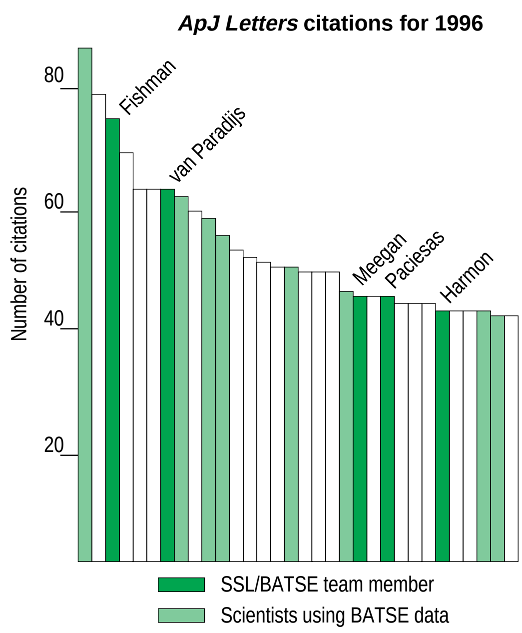
'96 headliner

Bursting with mystery

SSL's Burst and Transient Source Experiment (BATSE) continues to serve as the single most important experiment for investigation of the mystery of gamma-ray bursts, the most puzzling question in high-energy astrophysics. In its fifth year of operation aboard the Compton Gamma Ray Observatory, BATSE stares at the entire sky to capture flashes of gamma radiation which likely come from beyond our galaxy.

Significant discoveries during 1996 included the "bursting pulsar" and a quadruple-burst event. The bursting pulsar is in our galaxy but unlike any object seen before. This "one man band," as dubbed in *USA Today*, produces bursts of gamma-rays and X-rays, and behaves like a normal pulsar — the first time that both behaviors have been seen in the same object. Also unique was the quadruple burst, a series of four bursts — possibly related to each other — within two days from the same region of the sky.

One measure of BATSE's leadership in astrophysics is the citation index of *The Astrophysical Journal: Letters*, the pre-eminent North American, peer-reviewed journal for timely and important results in astrophysics. Of the top 35 most-cited scientists, five are on the SSL BATSE scientific staff; another eight use BATSE data.



BATSE scientists working in SSL were cited most often (excluding self-citation) in *The Astrophysical Journal: Letters* in 1996, a measure of the importance of SSL's research in high-energy astrophysics.

'96 headliner

The longest satellite

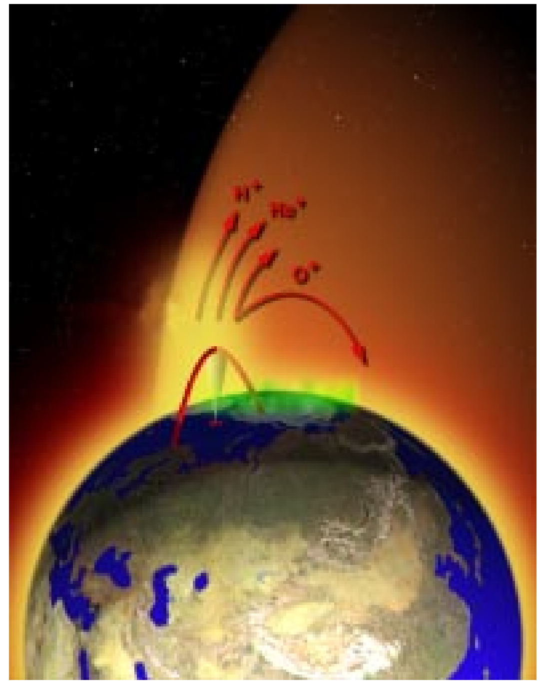
During February 1996, the Space Sciences Laboratory participated in the Tethered Satellite System reflight (TSS-1R) aboard STS-75, ranked as one of 1996's "top 100" science stories by *Discover* magazine. Although the tether broke (at 19.7 km) near full deployment, as is often the case in science, the unexpected provided the greatest excitement and scientific return. The magnitude of electrical currents in the tether showed that charge collection from the ionosphere by the satellite was many times more efficient than what theory predicted. In addition, the tether break afforded an opportunity to demonstrate boosting the orbit of a satellite by means of momentum transfer.

Three special sessions at the December 1996 meeting of the American Geophysical Union (AGU) were dedicated entirely to scientific results from the Tethered Satellite mission. The use of tethers in space remains a promising tool for future science and engineering missions.

'96 headliner

All the aurora, all the time

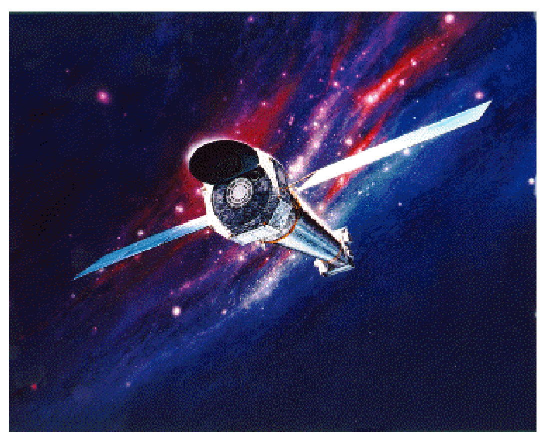
Two SSL instruments, the Ultraviolet Imager (UVI) and the Thermal Ion Dynamics Experiment (TIDE), were orbited with other instruments aboard the Polar spacecraft on Feb. 24 to study the dynamic region where Earth and space meet. With UVI, the aurora borealis now can be seen in both day and night, year-round. Previous instruments had imaged the nightside aurora or portions of the dayside aurora. Unique filters on the UVI now allow observations throughout the year so scientists can track and map energy flowing down into the polar regions. UVI also was named by *Discover* magazine as one of the top 100 science stories of 1996. TIDE's discovery that nearly 50 tons of material spews from the Earth's poles each day is one of the most exciting in space physics in recent years. TIDE observed that a fountain of low-energy plasma (ionized gases) is flowing from the polar regions of Earth's atmosphere into space. With its neutralizing plasma source, TIDE can readily detect low-energy ions rising from the day side of the auroral ovals. To see more of the invisible, SSL was selected in 1996 to build an inner magnetosphere imager for a 1998 space mission.



SSL's TIDE instrument aboard Polar revealed a fountain of low-energy plasma rising from the Earth's poles into space (the lower arc depicts a 1995 rocket flight which provided supporting data).

Measuring a mirror

In 1998, Marshall will help put X-ray astronomy on the same footing as optical astronomy when the Advanced X-ray Astrophysics Facility (AXAF) is launched. As 1996 closed, the High Resolution Mirror Assembly was delivered to Marshall for calibration. X-ray mirrors are tubes that gently curve inward so the incoming X-rays graze at a shallow angle and are focused. Because AXAF must operate at far greater precision and accuracy than previous X-ray telescopes, the mirrors will spend several weeks being mapped in exquisite detail in Marshall's X-ray Calibration Facility. The mapping ensures that once it is in orbit, AXAF will meet its promise to be as exciting and revealing in X-rays as the Hubble Space Telescope has been in visible light.



Artist's concept of the Advanced X-ray Astrophysics Facility (AXAF) in orbit after launch in 1998. The heart of AXAF is the High-Resolution Mirror Assembly — behind the circular slots at the center — which MSFC started calibrating in December 1996.

Earth System Science

Global Hydrology & Climate Center
Lightning detection from space
Global temperatures from space
Middle atmosphere research

While every child is taught the water cycle in grade school, scientists are still learning the full range and depth of its subtle workings, including how the distribution, movement, and properties of water and water-vapor affect the Earth's climate. SSL research in Earth science, an important component of NASA's Mission to Planet Earth (MTPE), is carried out by scientists at the Global Hydrology and Climate Center (GHCC).

Taking the Earth's temperature

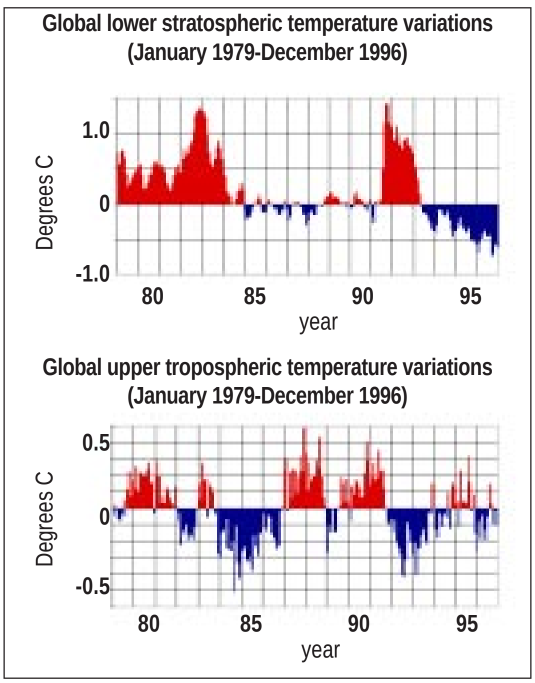
AMS Special Award

In January 1996, the American Meteorological Society presented its annual Special Award to Dr. Roy Spencer of SSL and Dr. John Christy of the University of Alabama in Huntsville for developing a precise global record of the Earth's temperature from polar-orbit weather satellites. This work has fundamentally advanced our ability to monitor the Earth's climate from space.

Using data gathered by spaceborne microwave sounding instruments, Spencer and Christy calculated seasonally adjusted temperature variations for the entire Earth, and with a data set that spans nearly 20 years, chronicled the temperature in the lower troposphere and the lower stratosphere.

Stratospheric data indicate extreme sensitivity to events such as volcanic eruptions by El Chichon in Mexico (1982) and Mt. Pinatubo in The Philippines (1991), and show a net cooling trend consistent with ozone depletion. Tropospheric data demonstrate a slight overall cooling trend.

Spencer and Christy continue their research. What once might have been an academic pursuit has implications beyond the laboratory. While other scientists may use the data to test the reliability of global climate models developed in a computer, national and international policymakers may use it to address complex and sometimes controversial environmental issues, such as global warming.



SSL and UAH investigators used 17 years of data from satellite instruments to determine that temperatures of the lower stratosphere (top) have cooled substantially, while the lower troposphere (bottom) has cooled slightly since 1979. Note that the scales are different and that the entire troposphere chart would fit within the 0.5-degree band of the stratosphere chart.

A windsock made of light

Measuring the wind is as simple as watching how fast the clouds go by. But when the clouds are not there, how can you even tell if the winds are blowing? That problem has vexed meteorologists even in the age of weather satellites which can see only cloud tops. The answer, being developed at SSL, is to use a laser to measure the speed of tiny particles in clear air.

During July, GHCC and its partners demonstrated the ability to measure atmospheric winds remotely using laser radar (lidar). A series of research aircraft flights using the Multi-center Airborne Coherent Atmospheric Wind Sensor (MACAWS) provided data to understand the meteorological processes, and is expected to assist in the design of a satellite to measure global winds from space. The wind sensor, a coherent Doppler lidar unit, uses pulses of laser light to measure winds from a distance by observing frequency shifts of the backscattered light that result from the motion of the air (the same technique as measuring a star's speed through its "red shift").

In 17 flights on the NASA DC-8 research aircraft, MACAWS measured wind speeds over Washington, Alaska, Texas, and California, and simulated operation of a satellite instrument. Additionally, the experiment gathered information on the operational capabilities of lidar and signal processor performance under less than ideal conditions. MACAWS and related work at SSL will assist us in designing a satellite instrument to measure global winds from space.

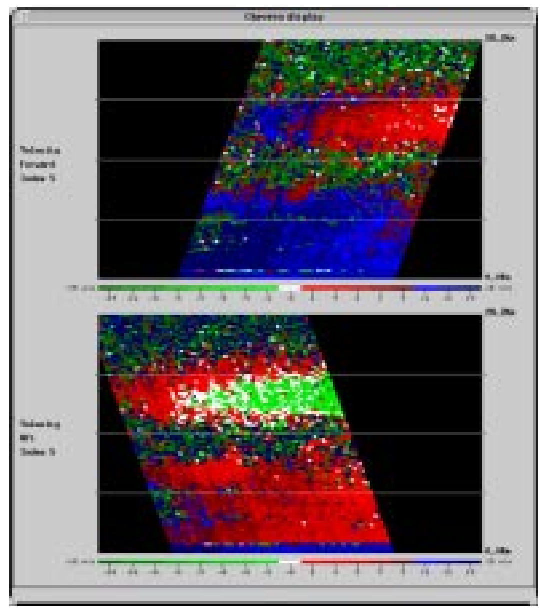
'96 headliner

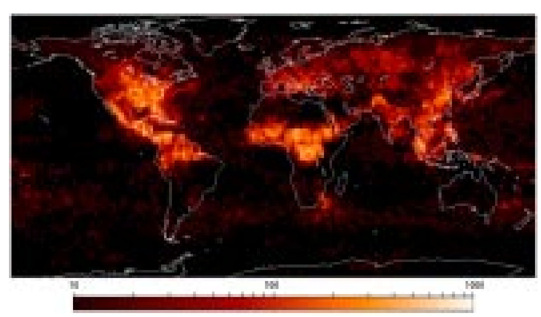
Lightning counts

Besides winds, lightning long has been an accepted measure of atmospheric energy. Since 1925, scientists have accepted that the global lightning flash rate is on the order of 100 flashes per second. In 1996, scientists from SSL's Earth System Science Division and the GHCC produced the first-ever high-resolution global maps of the annual cycle of lightning, observed from space by the Optical Transient Detector (OTD) instrument. Launched in April 1995, the OTD has yielded a new estimate for the global flash rate of lightning. Initial results from OTD's 15 months of operation show that the global flash rate is only about half the previous accepted value, or 40-50 flashes per second.

This finding has many implications for understanding atmospheric electrical phenomena. Detection of lightning is an important means to diagnose the intensity, structure, and life of thunderstorms. OTD data also indicate that lightning rates may be linked to tornado formation. This attracted the attention of national media in the wake of the hit movie, *Twister*.

MACAWS (above) was flown over the northwest aboard NASA's DC-8 research aircraft to determine how well lasers can measure winds by using the doppler effect with lasers. Colors in the plots below depict wind speeds as measured along the laser's line of sight.





Three months of observations by the Optical Transient Detector, show where weather systems release the most lightning strikes.

Microgravity Science and Applications

Leading edge of protein crystal growth science

"Brilliant" X-ray eyes

Aerogels

Advanced electronic materials

Marshall scientists continued probing the formation of novel materials, including the lowest-density material ever made by mankind, and the behavior of the ground on which we stand. Marshall also was designated by NASA as the lead center for microgravity science and applications.

'96 headliner

Frozen smoke

The most exciting news came from one of the most fragile and lightweight specimens ever produced by SSL. An SSL experiment aboard a Starfire rocket flown for the University of Alabama in Huntsville yielded the first space-produced aerogel, a foam-like product that has only three times the density of air — one writer called it "frozen smoke" — yet can protect the human hand from the heat radiated by a blowtorch.

Aerogels have been produced in ground-based laboratories, but have low quality because gravitational forces cause sedimentation leading to a dense foam near the bottom of the container and a thin foam near the top. An apparatus aboard the Starfire rocket produced a small specimen of aerogel with uniform cell size, wall thickness, and density. Potential applications for aerogels include highly efficient transparent insulation in window panes, skylights, and other commercial uses. Producing aerogels in space helps us understand better how to make aerogels on the ground.

Sample holder for the Mechanics of Granular Materials experiment is shown before being packaged in a water jacket for flight.

Sand castles in space

Anyone who has watched sand castles collapse at the beach will be familiar with the Mechanics of Granular Materials (MGM) experiment flown in 1996. MGM applies the microgravity environment of space to the behavior of soil under very low effective stresses. Ground-based experiments have long established the behavior of soil under high effective stresses, that is, high compression and sideways strains.

The values for low effective stresses are needed so we can understand better the mechanics of soil during earthquakes, the erosion of riverbanks and ocean floors, the movement of powdered pharmaceuticals while being manufactured, and many other phenomena. The results can have implications in civil engineering, conservation, industrial processes using powders, and even the exploration of the planets.

Brilliant X-ray eyes

A continuing challenge in protein crystal growth studies is the proper illumination of crystals by X-rays to make crystallograms from which the structure of proteins may be deduced. X-ray sources are like ordinary light bulbs: they radiate in all directions and a pinhole aperture must be provided to restrict the illumination to the subject.

Working with the State University of New York at Albany and X-ray Optical Systems Inc., also of Albany, SSL investigators developed capillary optics which capture X-rays and turn them into parallel rays. This allows crystallograms to be collected faster, or to be made with low-power sources on Earth or possibly aboard International Space Station.

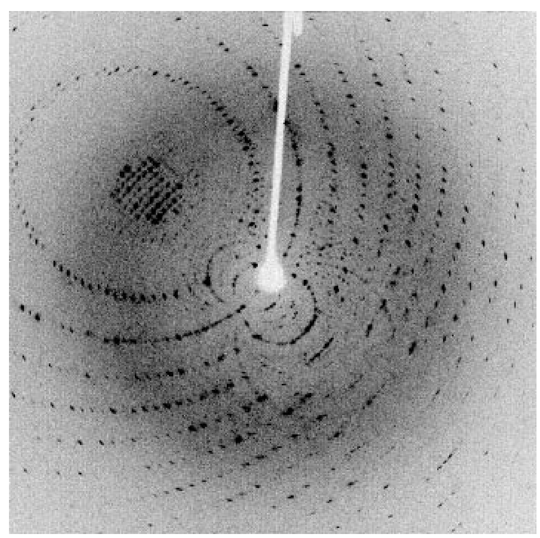
Diffusion-Controlled Apparatus for Microgravity (DCAM) was developed by SSL to grow protein crystals at slow, controlled rates in space. The patented design — a little larger than a 35 mm film can — has produced promising crystals in a long stay aboard the Mir space station.

Counteracting gravity

Intense magnetic fields, up to 100,000 times that of the Earth, were used to counteract the effects of gravity in growing crystals such as mercury-cadmium-telluride. Many of the defects that form in crystals are caused by convection (hot fluids rise, cold fluids sink). Intense magnetic fields reduce these flows by effectively freezing the convective motion while the material is still molten. These experiments were extremely helpful in interpreting results from SSL experiments with the Advanced Automated Directional Solidification Furnace (AADSF) on the second U.S. Microgravity Payload (USMP-2) mission. These data demonstrated for the first time the importance of residual flows when processing electronic materials in space.

Microgravity Science Laboratory

1996 saw SSL direct the third flight of the U.S. Microgravity Payload (USMP-3) in April, and start preparations for the USMP-4 mission in late 1997. SSL also was preparing for NASA's next Spacelab mission, Microgravity Science Laboratory (MSL-1). SSL scientists have played leading roles in Spacelab missions since Spacelab 1 in 1983. MSL-1 will carry investigations from Marshall, other NASA centers, and academic and international institutions. Both MSL-1, involving a four-person science crew, and the teleoperated USMP-4 will set the stage for SSL experiments aboard the International Space Station.



SUNY photo

Dots and shadows reveal the internal structure of crystals as shown in this X-ray crystallogram of lysozyme. Capillary X-ray optics, developed by SSL and the State University of New York-Albany, will provide better illumination for more complex proteins now under study.

Science Systems

SSL redesigned its web site to make results and works in progress more readily available to scientists and for the "science attentive" public. The address is: *http://wwwssl.msfc.nasa.gov*

The Science Systems Division provides much of the hardware and computational power needed by SSL scientists to conduct their research.

The Flight Experiments Branch provided leadership and engineering management for the development of the Interferometer Protein Crystal Growth experiment going to the Mir space station in September 1997. IPCG will measure the growth rate of protein crystals under diffusion control in microgravity. The branch also took the lead role in modifying the Scintillating Optical Fiber Calorimeter balloon flight hardware, and in directing and characterizing the second-generation optic housing and manipulator for the X-ray capillary optics system.

The Experiment Branch designed and built the second-generation Marshall Imaging X-ray Experiment, and the Liquid Xenon Gamma-Ray Detector Instrumentation and Control System. Both are to fly on balloons in 1997.

The Data Systems Branch supports computer applications, hardware and networks for SSL. In 1996, SSL scientists were among the first recipients of a leading-edge business and scientific desktop application environment that will become the standard for Marshall in 1997, and redesigned its web site for information serving to the public scientific audience. The branch also provided the TIDE Remote Data Access Facility 's new "CD-ROM jukebox" data archival system, BATSE's new high-capacity magnetic disk data archival system, and the Lightning Imaging Sensor project's multi-terabyte online storage archive.

SSL Management

For more information
Dr. John Horack, Office of the Director
MSFC - ES01
Huntsville, AL 35812
205-544-1872
john.horack@msfc.nasa.gov
http://wwwssl.msfc.nasa.gov

Executive Staff
Dr. Gregory S. Wilson, director
Dr. Ann F. Whitaker, deputy director
Dr. Eugene W. Urban, assistant director
Ernestine Cothran, associate director

Division chiefs
Dr. Sandor Lehoczky, microgravity science and applications
Dr. Frank Six, physics and astronomy
Dr. James Arnold, Earth system science
Larry Russell, science systems

Senior scientists
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Dr. Martin C. Weisskopf, X-ray astronomy
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Dr. Daniel C. Carter, biophysics

Communicating Scientific Knowledge

A principal mission of NASA is "to advance *and* communicate scientific knowledge… ." The exceptional performance of SSL in the latter part of this mission is manifested in several ways.

The sharing of scientific knowledge with the research community at large is demonstrated through the publication of more than 450 scientific papers — the second highest for SSL — in peer-reviewed journals, conference proceedings, and articles.

Additionally, SSL scientists serve their scientific disciplines and NASA programs by participating in Spacelab mission science activities, conference organizing committees, and science planning councils.

Our efforts to share many of our scientific results with audiences beyond the professional community are reflected in the large number and frequency of visitors to the laboratory, or outreach activities, including:

Bill Nye, The Science Guy. Visited Oct. 16-17 with production crew to develop story on BATSE.

Alabama Public TV *Integrated Science*. Visited Oct. 8-9 to develop episodes for APT series on microgravity science.

Agency for Integrated Technology. Visited Nov. 15 to develop astronomy-related education materials.

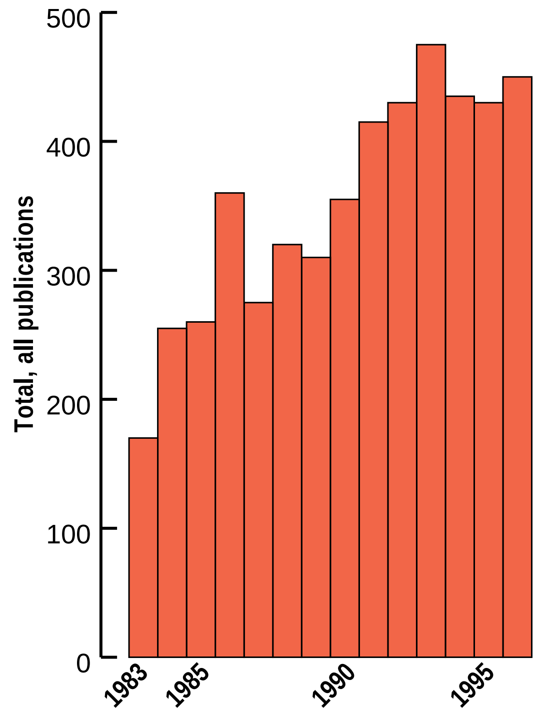
Stardate (NPR) broadcasts three BATSE stories, Oct. 14-16.

Savage Skies, PBS documentary feature (aired May 6-7), on severe weather featured SSL researchers.

Inside Space. *Science Fiction Channel* reporter Mike West interviewed Tom Moore and David Hathaway for story on new sunspot cycle, Dec. 5.

Discovery Channel. Production crew briefed May 31 on SSL activities.

Quadruple gamma-ray burst event announced in Chicago during the Texas Symposium on Relativistic Astrophysics, Dec. 17. The story makes headlines on CNN, Associated Press, other media.



SSL civil service employees have a strong heritage of broadly disseminating their results in refereed publications, conferences, books, and other media.

Notable Events

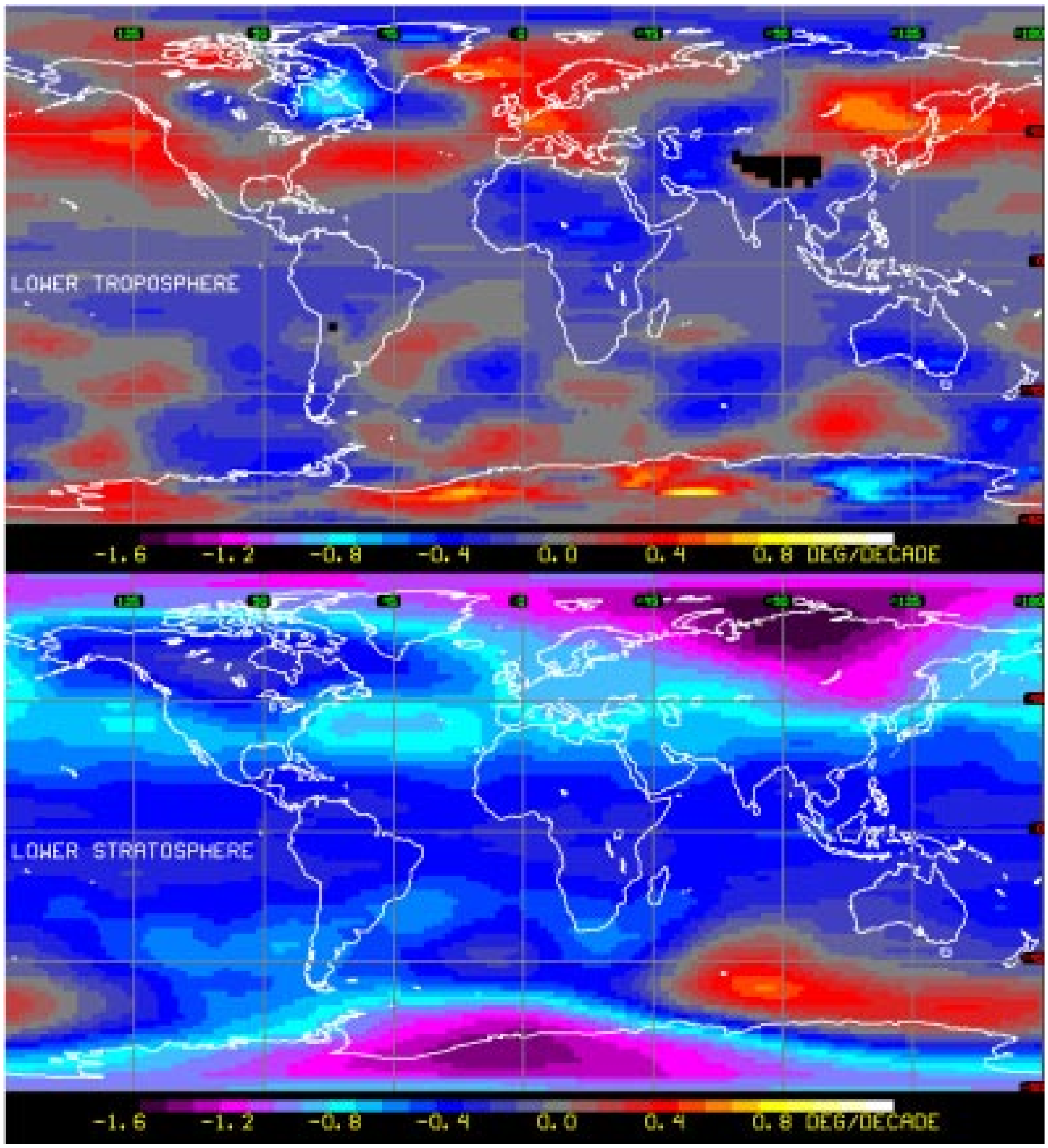
1996

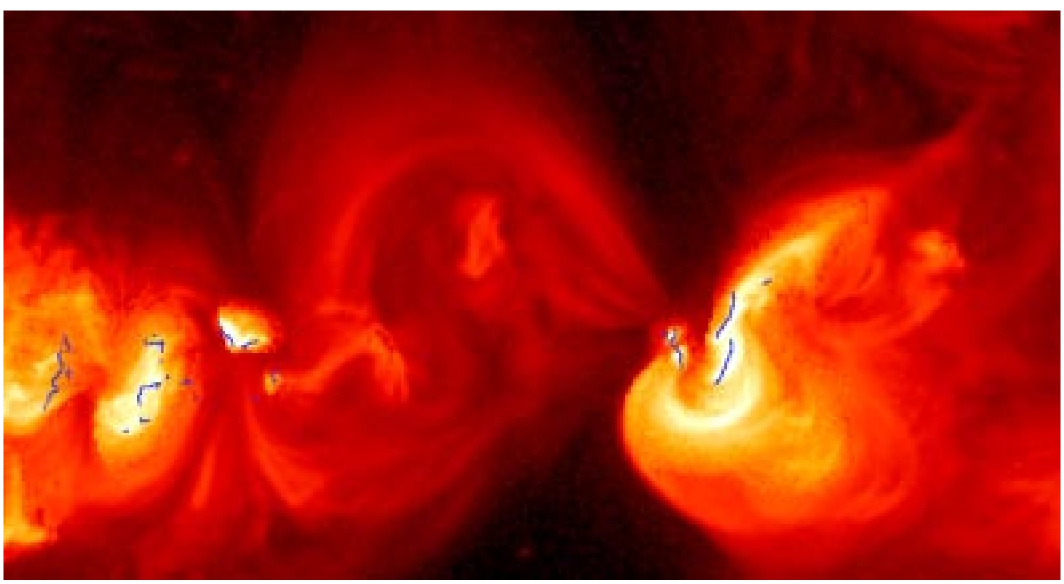
UAH Starfire rocket carries SSL aerogel experiment, April.
Five Space Shuttle missions carry more than 10,000 specimens for several protein crystal growth experiments.
U.S. Microgravity Payload (USMP-3), STS-75, Feb. 22-March 9.
Tethered Satellite System reflight (TSS-1R), STS-75, Feb. 22-March 9.
Polar satellite launched with TIDE and UVI, Feb. 24.
IMAGE selected for flight.

1997

First Microgravity Science Laboratory (MSL-1) mission, April.
Scintillating Optical Fiber Calorimeter (SOFCAL), March.
Marshall Imaging X-ray Experiment, March.
U.S. Microgravity Payload (USMP-4) mission, August.
Lightning Imaging Sensor, Tropical Rainfall Monitoring Mission, August.
Fourth biennial Huntsville Gamma-ray Burst Symposium, Oct. 15-19.

Written and designed by Dr. John Horack, SSL, and Dave Dooling, D^2 Associates.





National Aeronautics and Space Administration
Space Sciences Laboratory—ES01
Marshall Space Flight Center
Huntsville, Alabama 35812
http://wwwssl.msfc.nasa.gov